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T AND E GUIDELINES FOR AIRBORNE GENERAL SURVEILLANCE RADAR SYSTEMS

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T&E GUIDELINES FOR AIRBORNE GENERAL SURVEILLANCE RADAR SYSTEMS

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FOREWORD

This report is an outgrowth of the work of the Defense Science Board Task Force on Test and Evaluation, and the checklists herein have been derived from the study of past major weapon system programs.

The T&E expert in reading this volume will find many precepts which will strike him as being too obvious to be included in checklists of this type. These items are included because examples were found where even the obvious has been neglected, not because of incompetence or lack of personal dedication by the people in charge of the program, but because of financial and temporal pressures which forced competent managers to compromise on their principles. It is hoped that the inclusion of the obvious will prevent repetition of the serious errors which have been made in the past when such political, economic and temporal pressures have forced project managers to depart from the rules of sound engineering practices.

In the long run, taking short cuts during T&E to save time and money will result in significant increases in the overall costs of the programs and in the delay of the delivery of the corresponding weapon systems to the combatant forces.

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T&E GUIDELINES FOR AIRBORNE GENERAL SURVEILLANCE RADAR SYSTEMS

The checklist items presented here are specifically applicable to airborne general surveillance radar testing and evaluation. It is suggested that the user of this volume also refer to the Report of the Defense Science Board on Test and Evaluation which contains general checklist items also applicable to this system T&E program. The checklist items presented here are organized into time phases of the acquisition process oriented to the DSARC cycle.

The checklists cover various aspects of the major activities that should be underway during a given time period. Hence, a checklist might cover the (1) evaluation of work that occurred in the previous phase, (2) conduct of tests planned in the previous phase and executed in the subject phase, and (3) plans and other preparatory actions for test schedules to be conducted in a subsequent phase. For reasons such as this, items on some subjects, such as development test plans, may appear in more than one phase. In addition, since the Services and the DSARC have flexibility in deciding how rapidly to progress in the validation phase, there may be cases where the Request for Proposals (RFPs), proposal evaluations, source selections, or contract negotiations may occur after the DSARC approves full-scale development instead of before. For this reason, it is recommended that previous checklists in the Validation Phase be reviewed when entering the Full-Scale Engineering Development Phase. The following are the phases used in this report.

CONCEPTUAL PHASE

The checklist items in this phase are for guidance in evaluating T&E activities during the Conceptual Phase of the acquisition of the system. This phase (often research and exploratory development) precedes the first DSARC milestone and is focused on the development of a weapon system concept that offers high prospects of satisfying an identified military need.

Although not called for in DoD Directive 5000.1 specifically, the objectives of this phase should be:

1. To verify that there is a military need for the proposed system.
2. To demonstrate that there is a sound physical basis for a new weapon system.
3. To formulate a concept, based on demonstrated physical phenomena, for satisfying the military need.
4. To show that the proposed solution is superior to its competitors in terms of potential effectiveness, probability of success, probable cost, impact on the U.S. military posture, and development risks.
5. To analyze the technology outlook and the military need to show that it is better to start advanced development now rather than to wait for future technological improvements.
6. To identify the key risk areas and critical issues that need to be resolved before full-scale development is initiated.

The most important product of this phase is the Development Concept Paper (DCP) or its equivalent. The DCP defines program issues, including special logistics problems, program objectives, program plans, performance parameters, areas of major risk, system alternatives, and acquisition strategy.

VALIDATION PHASE

The checklist items in this phase are for guidance in conducting T&E during the Validation Phase (the time between when the DSARC recommends approval of the DCP for the first time and when the DSARC recommends full-scale development of the system).

While these objectives are not spelled out in the DoD Directive 5000.1, the objectives of the Validation Phase should be to confirm:

1. The need for the selected system in consideration of the threat, system alternatives, special logistics needs, estimates of development costs, preliminary estimates of life cycle costs and potential benefits in context with overall DoD strategy and fiscal guidance.
2. The validity of the operational concept.
3. That development risks have been identified and solutions are in hand.
4. Realism of the plan for full-scale development.

In the pursuit of the above objectives, it is likely that advanced development T&E will be conducted to resolve issues. In some cases, an RFP for full-scale engineering development will be prepared, proposals will be received and evaluated, and contracts negotiated in preparation for seeking DSARC approval for the next phase. Therefore, some checklist items are included to help ensure that this work properly reflects the T&E interests in this and subsequent phases. For example, the RFP must include adequate guidance to ensure that sufficient resources and time are available so that engineering effort can properly support the initial DT&E with hardware, software, technical data, and training.

The primary emphasis of OSD/T&E activities is with items 3 and 4 above. Special attention should be given to the planning of IOT&E activity as it is incorporated in the engineering development contract as well as the DT&E associated with addressing the critical issues and areas of major risk identified in the DCP.

FULL-SCALE ENGINEERING DEVELOPMENT PHASE

The checklist items contained in this phase are for guidance in conducting T&E during the Full-Scale Engineering Development Phase. This includes the major DT&E and the IOT&E conducted prior to the major production decision. By this time, the system is well-defined and is becoming a unique item and, hence, sound judgment must be applied in using these checklist items.

To enter the Engineering Development Phase, the DSARC will have:

- Confirmed the need in consideration of the threat, alternatives, logistic needs, cost, and benefits.
- Identified development risks.
- Confirmed the realism of the development plan.

Given the above, the primary objectives of the DT&E should be to:

1. Demonstrate that the engineering and design and development process is complete and that the design risks have been minimized (the system is ready for production).
2. Demonstrate that the system will meet specifications.

The primary objectives of the IOT&E should be to:

3. Assess operational suitability and effectiveness.
4. Validate organizational and employment concepts.
5. Determine training and logistic requirements.

In addition, the validity of the plan for the remainder of the program must be confirmed by the DSARC before substantial production/deployment will be recommended to the Secretary of Defense.

The level of OSD/T&E activity is highest during this phase. The IOT&E plan must be designed, the tests conducted, and the data analyzed to evaluate the inputs associated with the primary objectives. These tests should not be conducted until the primary objectives of the DT&E have been met. Thus, OSD/T&E activity is required to assess that the DT&E major milestone--the system is ready for production--has been achieved. Close monitoring of the T&E Service activity is required during the latter stages of this phase.

SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

The checklist items contained in this phase are for guidance in conducting T&E after the substantial production decision has been made by the DSARC. This includes DT&E and follow-on OT&E to be conducted on the early production items.

To enter the Production/Deployment Phase, the DSARC will have reviewed the program to confirm:

- The need for the system.
- A practical engineering design with adequate consideration of production and logistic problems is complete.
- All technical uncertainties have been resolved and operational suitability has been determined by T&E.
- The realism of the plan.

The primary objective of the DT&E in this phase should be to:

1. Verify that the production system meets specifications.

The primary objectives of the follow-on OT&E should be to:

2. Validate the operational suitability and effectiveness.
3. Optimize organization and doctrine.
4. Validate training and logistic requirements.

At this point, the OSD/T&E activity is similar to that in the previous phase; however, much of the testing is verification that the production system performance is as expected. Hence, most of the items in the previous phase are appropriate to this phase, especially those related to OT&E.

I. CONCEPTUAL PHASE

During this phase the program is being conceived and the DCP or its equivalent is being prepared. The test and evaluation checklist covers the following:

1. Test Program/Total Costs
2. Test Facilities and Instrumentation
3. Operational Scenario
4. Combining Untried Systems
5. Documentation

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1. TEST PROGRAM/TOTAL COSTS

Prior to DSARC I, all the phases of the test program should be addressed so that the approximate total costs and development schedules include consideration of all likely activities in the over-all program.

In an airborne general surveillance radar program, these might include the cost for range support during the R&D effort, new test range instrumentation or facility requirements, the cost of the OT&E program (both IOT&E and follow-on OT&E including test gap closing provisions), and the cost of special tests, such as special antenna ranges for measuring ultra-low antenna side lobes, scale modelling to obtain preliminary data on interaction between the antenna and aircraft, and special simulators to exercise the ECCM features of the radar system.

2. TEST FACILITIES AND INSTRUMENTATION

Before DSARC I, test facilities and instrumentation requirements to conduct operational tests should be identified, along with a tentative schedule of test activities.

The applicability of the test ranges, the adequacy of the facilities and instrumentation, and the availability (at the appropriate time) of real or simulated enemy jammers should be verified. Insofar as possible alternative approaches (different ranges, etc.) and necessary instrumentation improvements should be specified. Of prime importance are the constraints to be placed on the test because of range, instrumentation, and target radar availability. If these factors are found to cast significant doubt on the meaningfulness of the test data because of a lack of operational realism, the steps necessary to assure meaningful data should be identified and planned before inclusion in the DCP.

3. OPERATIONAL SCENARIO

Analytic and empirical studies should be conducted prior to DSARC I to insure that the range of critical performance characteristics has been specified.

Each performance characteristic, such as clutter rejection requirements, vulnerability to countermeasure, mutual interference, etc., specified should be measurable through laboratory or full-scale testing. The test plan and the number of tests should be prepared so that meaningful results and conclusions can be drawn (at suitable confidence limits if necessary). If a given target detection range is specified, testing at one or two closing and opening velocities, at two or three altitudes, in two or three different clutter environments may satisfy the requirements for meaningful test results. Testing in advanced development should be planned to explore the radar detection and clutter rejection performance over a broad range of terrains and altitudes so as to provide insight into system performance over the expected operational range and not just at a single point. Inputs from the ORT (Overland Radar Technology) program should be used to provide clutter data.

4. COMBINING UNTRIED SYSTEMS

Whenever possible, try to avoid combining untried systems prior to the initiation of a radar test program.

A radar system developed for use in a fighter aircraft incorporated as a new feature a built in test equipment (BITE) system. This permitted onboard checking and troubleshooting of the radar. Since the system was new, it was not too well understood initially and many problems arose in connection with the BITE. Much development time and effort required to get the BITE working properly took up time that should have been spent on the development of the radar itself.

5. DOCUMENTATION

Prepare adequate documentation to provide full benefit from development history for future programs. Use this documentation in developing T&E plans for subsequent programs.

In the development of one new radar system (which extended over almost a 15-year period), no effort had ever been made to provide overall documentation of the program. Historical development of the system had never been

thoroughly documented and no attempt was made to conduct a scientific analysis of the data. The only extensive analysis of the data was limited to systems performance evaluation prior to the determination of the procurement source. As a result the lessons learned on this program were not adequately documented and hence not available for the development of future similar systems testing and evaluation plans.

II. VALIDATION PHASE

In the Validation Phase the issues raised by the DCP may be resolved by conducting tests on the system. The development and operational plans will be defined in considerable detail. Additional test and evaluation checklist items are:

1. Compatibility of Components
2. Software
3. Flight Testing
4. Testing in the Presence of Clutter
5. Brassboard Stage Changes
6. Antenna Patterns
7. Simulations
8. Testing Objectives
9. Reliability Testing Plan
10. Test Scheduling
11. Progressive Testing
12. Demonstration Testing

The reader should review the previous checklist items since many of them will be appropriate to this phase.

1. COMPATIBILITY OF COMPONENTS

Be sure that items which must work compatibly in the airborne general surveillance radar system are developed as a unit. This is particularly important for radar transmitters and transmitter tubes.

One manufacturer used some long lead time money to develop a power transmitter in cooperation with another manufacturer who was concurrently developing the needed klystron tube. This permitted testing and demonstration of the high power transmitter at an early date in an acceptable configuration. In a number of other cases the transmitter tube, which has frequently been the pacing element, was funded independently before the procurement of the radar. Interface problems and a loss of flexibility in trade-offs between the tube and the transmitter almost invariably resulted.

2. SOFTWARE

Test and evaluation should ensure that software products associated with the ECM and data processing subsystems are tested appropriately during each phase.

Software has often been developed more as an add-on than as an integral part of the overall system. Software requirements need the same consideration as hardware requirements in the Validation Phase. Usual practices often do not sufficiently provide for testing the software subsystem concept. Often the facilities available to contractors for software development and verification are critical to schedule and cost. Failure to thoroughly check out the software on several ECM programs resulted in inability to properly classify certain emitters.

3. FLIGHT TESTING

Engineering flight tests should be conducted on the entire radar system as soon as possible.

An airborne general surveillance radar must be tested in its natural airborne environment. Each new installation and configuration is unique and must be reevaluated. A system cannot be tested on the ground and shipped for field installation; flight testing is also necessary. Test bed aircraft should be used for early flight testing. In these tests, the transmitter mounting configuration and antenna pointing directions relative to the aircraft should be carefully selected to ensure that realistic clutter rejection tests are performed. The system must have excellent clutter rejection performance for the automatic detection system to operate properly. Flight tests should be flown over representative terrain so that meaningful conclusions can be drawn from the data. During these tests, it is important to provide instrumentation to record the critical functions; reliance on the radar operator's memory of what happened should be avoided.

4. TESTING IN THE PRESENCE OF CLUTTER

Testing of an airborne general surveillance radar system should occur in the presence of actual clutter. This means that an airborne test is mandatory using typical or representative terrain to provide real clutter information.

If the parameters which affect clutter (primarily frequency, pulse-width, and PRF) are essentially unchanged from a proven design, airborne testing requirements are minimal. If any of these parameters is changed significantly, a major test program should be initiated at the earliest possible date.

The use of a synthetic target generator is strongly recommended in conjunction with the evaluation of actual clutter effects. It is necessary to use at least one live target as a reference. Local aircraft traffic which may easily number into the hundreds is also valuable in evaluating system performance. Additional synthetic targets provide information on the behavior of the system over the full performance envelope of the system without the need for extensive external preparation and extensive time requirements. Note that the aircraft continues to be flown

in typical flight profiles so that the actual ground clutter will be present in evaluating the synthetic targets.

5. BRASSBOARD STAGE CHANGES

During the brassboard stage of a radar development program provision should be made for changes in software which can be performed easily and in timely fashion.

As an example of what can be done, one manufacturer, during a competitive fly-off which lasted nine months, made a parametric change in their radar on the average every day and a major parametric change on the average of every second day. A major contributor to this performance was a design using digital intercommunication between chassis, and a bus architecture similar to that now used in many computers. In addition to allowing fast change of radar parameters with a software change, it also avoided major rewiring of the aircraft (a problem for relatively minor modifications throughout the operational life of a radar). Another consideration in this performance was a design which had been proven reliable so that no significant time was lost on repairs. This, in turn, was due to use of highly reliable components and provisions for in-aircraft servicing.

6. ANTENNA PATTERNS

Measure antenna patterns in all situations which are meaningful for operation.

Antenna patterns should be measured on an antenna range, on the aircraft in which the radar is to be flown, both with and without IFF operational. Antenna testing should also include evaluation of cooling and beam stabilization if used.

7. SIMULATION

Analysis and simulation should be conducted, where practicable, before each phase of development flight testing.

Analysis, simulation and other ground testing should be used to predict test outcome and to establish test objectives. The flight test may then be accomplished to achieve the objectives. Comparison of simulation and flight test results provides better understanding of the system. One radar manufacturer first developed a simulator for their radar, then combined it with a war game model to evaluate the radar system. This approach was of great use to the manufacturer in evaluating the impact of proposed changes in the radar relative to the overall effectiveness of the system.

8. TESTING OBJECTIVES

Test conditions during validation testing should be determined by the primary objectives of that test, rather than by more general considerations of realism, etc.

Whenever, in the interest of obtaining advanced engineering data, a non-tactical, non-operational configuration is required for testing, the results of the tests should not be challenged by the fact that the configuration was not tactical or operational. For example, if, in the development of an airborne general surveillance radar system, problems with the signal processor preclude adequate clutter rejection, it may be desirable to use a target equipped with a transponder as an aid to testing the other aspects of the radar system.

9. RELIABILITY TESTING PLAN

A reliability testing plan should be included as a part of the T&E plan for an airborne general surveillance radar.

In order to provide reasonable confidence in the reliability of an airborne general surveillance radar system, a large test sample size or a long test period is indicated. A study of the tradeoffs among sample size, test duration, and the confidence level should accompany any reliability testing plan. If, for some reason, the sample size or test duration is less than desirable (which is the normal situation), a plan for showing how the reliability goals are to be demonstrated must be prepared.

10. TEST SCHEDULING

Before DSARC II, the nature of the schedule for the OT&E plan should be addressed.

In general, the OT&E plan should include engagements in the environments in which the new system is expected to operate. Airborne general surveillance radar testing may be addressed in several phases, such as:

(a) One-on-one testing against available simulators of the assumed targets.

(b) Single aircraft detection and tracking in a jamming environment.

(c) Multiple aircraft detection and tracking in an interference environment caused by other radars or electronic equipment as well as jammers.

(d) Comparative testing of the new radar system with existing similar systems to demonstrate the increased capability.

Test range and resource requirements should be estimated, and, if inter-service testing is contemplated, preliminary plans for such testing should be coordinated with the cooperating service.

11. PROGRESSIVE TESTING

The design of the set of tests to demonstrate system feasibility prior to DSARC II should be based on a building block concept.

High technical risk items should be tested early with subsequent tests incorporating more of the hardware until the complete system concept has been demonstrated feasible. For example, if the high risk item is a high power tube, then the demonstration of tube performance should be conducted prior to the transmitter system test.

12. DEMONSTRATION TESTING

Major tests must be accomplished and system feasibility adequately demonstrated before the system is allowed to move to the next phase of the acquisition process.

For example, before the system is allowed to go into the IOT&E phase, all engineering tests should be complete; before the Full-Scale production

phase is entered, the IOT&E of the total airborne general surveillance radar system should have been successfully performed by the using command; prior to deployment of the system to the user, successful completion of the acceptance testing of the initial production items must have occurred.

III. FULL-SCALE ENGINEERING DEVELOPMENT PHASE

In this phase, the T&E plans developed in the Validation Phase will be refined and the development testing conducted. IOT&E plans will similarly be refined; personnel will be assigned and trained and the IOT&E conducted. The full-scale development checklist includes:

1. Radar System Performance Evaluation
2. Avoiding Testing Delays
3. Temperature Cycle Tests
4. Interfaces with Other Systems
5. Mechanical Components
6. Ground Test
7. Maintenance of Flexibility
8. Value of Envelope Expansion
9. Maintenance Data Package
10. Production Decision

It is suggested that the checklists for the previous phases, particularly the Validation Phase, be reviewed by those interested in a checklist for full-scale development.

1. AIRBORNE GENERAL SURVEILLANCE RADAR SYSTEM PERFORMANCE EVALUATION

Evaluate the performance of the radar system including signal processing capabilities and interaction of the high power tube and the transmitter, taking into account all related factors.

This includes tracking, taking into account main beam clutter, digital to analog conversion, subclutter visibility including coherency (transmitter stability), amplitude stability and filter sidelobes, sidebands, bandwidth (both instantaneous and operating), frequency agility, PRF agility, pulse compression, software (both programmable and hardware), range velocity ambiguity removal for both software and hardware, and cooling. Clutter rejection capability should be evaluated on the basis of a specified target size in a specified type of terrain. Verify that large point targets do not cause false alarms in the automatic detection system. Evaluate the data displays in the airborne environment, and the receiver design including factors such as ECCM (vulnerability of the system to countermeasures should be evaluated), dynamic range, sensitivity requirements, and false alarm threshholds. The T&E should include the effects of such factors as frame time and dwell time and should be conducted using ont only the primary modes but the backup modes, degraded modes, and manual modes. Ground support equipment should be evaluated in conjunction with the testing of the airborne equipment.

2. AVOID TESTING DELAYS

When testing is delayed because of the non-availability of critical sub-system components, off-the-shelf interim components should be used as substitutes until the proper components are available.

As long as the off-the-shelf components can function acceptably within a defined range of interest, the rest of the system can be tested, thereby facilitating the progress of the test program. Clearly, this cannot be continued indefinitely, but it should serve to reduce the lingering influence of long lead time components that are not available on time. Selected tests may have to be repeated when the proper component is available.

For example, it may be possible to carry out meaningful system testing without having a full power transmitter; clutter rejection tests, tests of antenna side lobe interaction with signal processor, and demonstration of th range/velocity ambiguity removal algorithms in an actual clutter environment may all be done without a full power transmitter.

3. TEMPERATURE CYCLE TESTS

Special attention should be devoted to temperature cycle test results since they will help identify component and structural interface problems.

Specifically, the temperature cycling tests should simulate the expected temperature environments with respect to the numbers of and peak excursions of the cycles.

4. INTERFACES WITH OTHER SYSTEMS

Whenever possible, the IOT&E (as well as the follow-on OT&E) of an airborne general surveillance radar should be planned to include any other systems which must have a technical interface with the new system.

For example, radar equipment should be tested on all the existing aircraft for which it has been programmed, and the interface with the pertinent C^3 should be tested. Whenever more than one system is involved, specific attention should be directed to the interfaces of the systems, especially the display and control subsystems.

5. MECHANICAL COMPONENTS

Ground test all mechanical components of an airborne general surveillance radar system prior to installation in the aircraft. Repeat testing in the airborne environment.

This includes items such as rotary joints, the radome itself, the drive system, the angle sensor and any other mechanical components. It must be remembered that aerodynamic loads as well as gravity loads are important in the airborne environment.

6. GROUND TEST

Where available, it is highly desirable to have a hot bench on the ground which can be used to supplement the airborne system.

The purpose of a hot bench is to be able to test items which are being run in the air without the necessity for an actual flight. Faulty components may then be identified and replaced prior to performance of a test.

7. MAINTENANCE OF FLEXIBILITY

Be sure that the production design stage has been reached before the flexibility of the brassboard version is eliminated.

This includes any preliminary attempts at cutting weight which may unfavorably influence the flexibility capabilities.

8. VALUE OF ENVELOPE EXPANSION

Contract requirements and incentives should not be based on extreme corners of the theoretical performance envelope unless there is a high pay-off for such performance.

For example, considerable extra test effort, time, and money might be spent on getting completely satisfactory clutter rejection performance over urban localities when this environment is not usually encountered. Thus a contract that blindly specifies that the clutter rejection characteristics must be fully compliant throughout the performance envelope may lead to a non-cost effective design.

At the same time, the contract incentive fee criteria should not constrain the developer from exploring the full performance envelope. For example, inability to reject ground moving targets should not preclude testing of this capability merely because it will reduce payments or jeopardize continuation of the program. In addition, do not allow performance test criteria to be limited to an oversimplified evaluation criterion, such as whether or not the target can be detected by the radar under ideal"look-up" conditions.

9. MAINTENANCE DATA PACKAGE

Prior to the decision to go into full-scale production of an airborne general surveillance radar system, a complete technical/maintenance data package must be prepared and tested to ensure that the system can be maintained.

The testing of this package should be considered as an essential part of DT&E and also as an essential part of the IOT&E of the system. Criteria for successful demonstration of this package should be established in both types of tests.

10. PRODUCTION DECISION

Conduct IOT&E before making a production decision. Anticipate production problems if testing is still being done after initiation of production.

Because of the need for early delivery of an airborne general surveillance radar unit, development testing was done on a continuing basis during early production. Testing overlapped approximately the first 10 percent of the sets which were eventually built. As problems were identified most of them could be cured but at the expense of production efficiency. Changes were made during the production run to incorporate fixes which were required, but this tended to interfere with a smooth running production line. In this case loss of production efficiency was accepted in order to meet time oriented milestones.

IV. SUBSTANTIAL PRODUCTION/DEPLOYMENT PHASE

This phase occurs after the DSARC substantial production decision. Follow-on OT&E will be conducted with production hardware. It is suggested that the checklists for the previous phases, especially the last phase, be reviewed since many of the items will be applicable for this phase. The primary checklist item for this phase is:

FOLLOW-ON OT&E

The follow-on OT&E plan should include tests of any operational modes not previously tested in IOT&E.

All operational modes, including backup modes, should be tested in the follow-on OT&E because the software interface with the production hardware system should be thoroughly evaluated. Otherwise, small easy-to-fix problems could seriously impair overall system performance under adverse conditions.

The test phase should be extended if necessary to evaluate system adequacy in the face of new operational modes that become known late. The follow-on OT&E activity and the continuous operational testing that usually follow system deployment must be coordinated to make most effective use of resources in testing new operational modes.

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